# 4.11 GEOLOGICAL RESOURCES/STRUCTURAL INTEGRITY REVIEW

The geology, seismicity and soil conditions at the Long Wharf directly affect the structural integrity of the Long Wharf terminal structures. Using updated seismic information, the Long Wharf has been structurally upgraded, to accommodate a 475 year return period earthquake. This facility has the potential to spill large amounts of oil to the surrounding environment, and mitigation measures must be taken to reduce this risk. This section discusses the mitigation measures and alternatives to the proposed Project.

The Long Wharf is just off the eastern shoreline of upper San Francisco Bay, within the city of Richmond. The Long Wharf is connected to the shore by a 4,200-foot-long (.80 miles) causeway (Moffatt & Nichol Engineers 1997). A steel trestle and the low sulfur fuel oil (LSFO) pipeway run parallel to the causeway. The Long Wharf consists of a main Long Wharf, repair wharf (Berths A and B), and the central section (Figure 4.11-1). Additional detailed figures were presented in Section 2.0, Project Description. The main part of the Long Wharf is approximately 2,460 feet (.47 miles) long and 110 to 132 feet wide, extending approximately 670 feet south and 1,790 feet (.34 miles) north from the causeway. The repair wharf is approximately 480 feet long and juts out to the southeast. The top of the Long Wharf is at an elevation of approximately 15 feet above mean lower low water (MLLW). The mud line beneath the main Long Wharf varies from approximately 40 feet below MLLW on the seaward side and 20 feet below MLLW on the landward side, and is approximately 4 feet below MLLW beneath the causeway.

An extended description of the Long Wharf is included in this section as well as an overview of a recently completed comprehensive seismic upgrade program.

## 4.11.1 Environmental Setting

### Geotechnical Considerations

*Geology*

<u>Regional Geology</u>

San Francisco Bay is a northwesterly trending structural depression that lies along the boundary of the Pacific and North America tectonic plates. The Bay is within the Coast Ranges geomorphic province of California, which is characterized by a series of nearly parallel mountain ranges (Goldman 1969). Active faults, including the San Andreas, Hayward, and Calaveras Faults, roughly parallel the western and eastern limits of the Bay. The Bay began forming during the Pleistocene Epoch, approximately 2 million years ago, the San Francisco-Marin block began to tilt eastward along the Hayward Fault. The eastern side of the block became a depression and filled with sediment and water.

Figure 4.11-1 – Richmond Long Wharf Site Plan

Bedrock units exposed in the eastern portions of the Bay range from Jurassic-Cretaceous to Quaternary age (approximately 135 million years old to recent). The oldest bedrock units (Jurassic-Cretaceous age) include the Franciscan Formation, which consists of interbedded sandstone and shale, limestone, radiolarian chert, and metavolcanic rocks (Goldman 1969). The Franciscan Formation is west of the Hayward Fault, and is exposed in the hills along the San Pablo Peninsula. East of the Hayward Fault, a thick sequence of Tertiary age sandstones and shales of the Great Valley Sequence overlies the Franciscan Formation. Along the eastern shoreline of the Bay, layers of Quaternary-age alluvial sediments known as "Bay Mud" mantle the Franciscan Formation. Figure 4.11-2 depicts the regional geologic conditions of the San Francisco Bay Area. Since Cretaceous time, the Bay Area has undergone numerous episodes of faulting and folding. As such, rock units exposed along fault zones are typically sheared and highly weathered.

Site-Specific Geology

Site-specific characteristics of the underlying geologic conditions described in this section are based on regional studies of the Bay and a site-specific study performed by Dames & Moore (1998). Regional studies include those by the California Division of Mines and Geology (CDMG) (Goldman 1969; Treasher 1963), the USGS (Atwater et al. 1977; Lawson 1914), and others (Rogers and Figuers 1992). The site-specific study prepared by Dames & Moore (1998) provides a summary of the underlying geologic units, which was used for seismic retrofit of the Long Wharf.

Beneath the Long Wharf, the Bay bottom is covered with late Quaternary-age Bay Mud, which overlies bedrock of the Franciscan Formation (Goldman 1969). The top of the Franciscan Formation beneath the Long Wharf is estimated to lie approximately 50 to 150 feet below MLLW (Goldman 1969). In the central portions of northern San Francisco Bay, the top of bedrock reaches depths of approximately 300 feet below MLLW.

During late Pleistocene and Holocene time, sea level fluctuated several times, allowing for the deposition of the Bay Mud. Gentle rolling hills and valleys dominated the offshore portions of the eastern Bay, and were exposed and subsequently submerged during changes in sea level. Various subunits of Bay Mud have been used by different geologists this past century (Lawson 1914; Trask and Rolston 1951; Goldman 1969; Rogers and Figuers 1992). For this report, the Bay Mud subunits of Goldman (1969) seem to correlate best with the soil profile described by Dames & Moore (1998). Goldman (1969) divided Bay Mud into three informal units: Younger Bay Mud, Bay Sand, and Older Bay Mud. The Bay Mud varies in overall thickness from approximately 50 to 150 feet, and increases in thickness westward from the shore to the main wharf (Goldman 1969).

Figure 4.11-2 – Regional Geologic Map of San Francisco Bay Area

The youngest unit, Younger Bay Mud, is of Holocene age, and consists of gray silty clay that is typically soft in the upper portions of the unit and semiconsolidated in the lower portions. The thickness of Younger Bay Mud beneath the Long Wharf varies from approximately 50 to 80 feet (Dames & Moore 1998). Dames & Moore (1998) designates Younger Bay Mud as Soft Bay Mud in their report. For evaluation purposes, they estimated an approximately 80-foot-thick layer of Soft Bay Mud beneath the main wharf, and a 50- to 60-foot layer beneath the causeway. Dames & Moore (1998) also describes a relatively thick, but laterally discontinuous, sand layer beneath the Soft Bay Mud. This sand layer is most likely equivalent to the Bay Sand as described by Goldman (1969). Stiff to very stiff clays, most likely equivalent to Older Bay Mud (Goldman 1969), underlie the Bay Sand and Soft Bay Mud (Dames & Moore 1998).

The Bay Sand and Older Bay Mud have an estimated combined thickness of 30 to 40 feet underlying the Soft Bay Mud. The Bay Sand consists of fine sand, and varies in thickness from 10 to 50 feet along the eastern portions of the Bay (Goldman 1969). The Bay Sand overlies or interfingers with the Older Bay Mud, which consists of dark greenish-gray, silty clay, with varying amounts of sand and fine gravel (Goldman 1969). Older Bay Mud and Bay Sand typically have higher in-place densities and lower water contents than Younger Bay Mud.

Based on a pile load test and their analyses, Dames & Moore (1998) concluded that driven piles can develop significant load capacity, primarily as skin frictional resistance, when embedded in the Soft Bay Mud. The load test was performed on an 18-inch-square prestressed concrete pile, driven approximately 60 feet below the mudline with the upper 53 feet in Soft Bay Mud and the lower 7 feet in stiff clay (Older Bay Mud). The Dames & Moore (1998) work was used for the structural rehabilitation of the Long Wharf to determine the capacity of the steel piles.

*Seismicity*

Regional Seismicity

The San Francisco Bay region lies along a major, seismically active plate boundary. The San Andreas Fault, which forms the boundary between the Pacific and North America tectonic plates, has produced numerous earthquakes in the Bay Area during historic and prehistoric times. Movement between the plates has created several other active faults parallel to the San Andreas, including the Hayward, Calaveras, Greenville, Rodgers Creek, and San Gregorio Faults. These faults create a zone of faulting approximately 50 miles wide through the greater San Francisco Bay Area. These faults are shown on Figure 4.11-3. The approximate distance from the site and estimated moment magnitudes for earthquakes along these faults are summarized in Table 4.11-1.

Figure 4.11-3 – Regional Fault Map of the San Francisco Bay Area

**Table 4.11-1**
**Known Active Faults in Site Vicinity**

| Fault | Distance from Site (miles) | Estimated Magnitude (Mw)* |
|---|---|---|
| Calaveras | 24 | 6.8 |
| Concord | 19 | 6.9 |
| Greenville | 25 | 6.9 |
| Hayward | 4.5 | 7.1 |
| Rodgers Creek | 16.5 | 7.0 |
| San Andreas | 14.5 | 7.9 |
| San Gregorio | 47 | 7.3 |

*** Mw - Moment Magnitudes from CDMG/USGS study (Petersen et al. 1996).**

Several historic earthquakes have occurred within the Bay Area on several of the major faults. Two historic earthquakes occurred in 1836 and 1868 along the Hayward Fault, which is the closest active fault to the site. Both of these earthquakes have estimated magnitudes of around 7. Slow movement, or creep, along the Hayward Fault is estimated to be approximately 9 millimeters per year (mm/yr) for a portion of the southern segment and around 5 mm/yr for the northern segment (Lienkaemper and Borchardt 1992). Joint studies by the CDMG and the U.S. Geological Survey (USGS) indicate that an earthquake with a maximum moment magnitude (Mw) of 7.1 could occur along the Hayward Fault (Petersen et al. 1996). In addition, the Working Group on California Earthquake Probabilities (1990) estimated that there was a 28 percent chance that a magnitude 7 or greater earthquake would occur on the northern segment of the Hayward Fault by 2020.

Other notable earthquakes include the 1838, 1906 (around magnitude 8), and 1989 (Mw 7.1) earthquakes on the San Andreas Fault. The 1906 and 1989 (Loma Prieta) earthquakes caused major damage to structures in the Bay Area. Estimated moment magnitudes of future earthquakes for various strands of the San Andreas in the Bay Area varies from Mw 7.0 to 7.9 (Peterson et al. 1996). The "Mare Island" earthquake of 1898, along the southern end of the Rodgers Creek Fault, is also of historic significance. Toppozada et al. (1992) believes that the earthquake epicenter was located near the southern end of the fault, and estimates its magnitude at 6.2.

<u>Site-Specific Seismicity</u>

The Long Wharf is located along the northeastern side of San Francisco Bay, between the San Andreas and Hayward Faults (Figure 4.11-3). The San Andreas and Hayward Faults are approximately 14.5 miles southwest and 4 miles northeast of the site, respectively. Large magnitude earthquakes have occurred along both of these faults within the last 200 years.

Active faults, as defined by the State Board of Mining and Geology (Hart and Bryant 1997), do not transect the Long Wharf. An active fault, as defined in the Alquist-Priolo Earthquake Fault Zoning Act, is one that has had surface displacement within Holocene time (about the last 11,000 years). The purpose of the Alquist-Priolo Act is to regulate development near active faults to mitigate the hazard of surface rupture (Hart and Bryant 1997).

Several inactive faults, including the San Pablo, Pinole, and Franklin are within several miles of the site. The San Pablo Fault is located approximately 1 mile northeast of the site. The Pinole and Franklin Faults are approximately 8 and 13 miles northeast of the fault, respectively. The Franklin Fault is believed to be the northern extension of the active Calaveras Fault.

The magnitude 7.1 Loma Prieta earthquake in 1989 is the largest earthquake to occur in the San Francisco Bay Area in the last 20 years. The epicenter of the Loma Prieta earthquake was approximately 63 miles southwest of the Long Wharf in the Santa Cruz Mountains. Strong ground motion instruments located near the Long Wharf measured peak horizontal ground accelerations of 0.12 to 0.13 g (g is equal to the acceleration of gravity) during the earthquake (Shakal et al. 1990). Peak horizontal ground accelerations of up to 0.64 g were measured near the epicenter in the Santa Cruz Mountains. Areas surrounding the Bay damaged most by the earthquake included the Marina District in San Francisco and the Cypress Street viaduct, in Alameda. Soft soils in these areas amplified the moderate levels of ground shaking.

Recently, Chevron has placed strong motion accelerometers on the Long Wharf. These accelerometers are discussed further in the Structural Condition of the Long Wharf subsection.

*Tsunamis*

Tsunamis are sea waves usually created by undersea fault movement or by a coastal or subsea landslide. Tsunamis may be generated at great distance from shore (far field events) or nearby (near field events). Waves are formed, as the displaced water moves to regain equilibrium, and radiates across the open ocean, similar to ripples from a rock being thrown into a pond. When the waveform reaches the coastline, it quickly raises the water level, with water velocities as high as 15 to 20 knots. The water mass, as well as vessels, vehicles, or other objects in its path create tremendous forces as they impact coastal structures.

Tsunamis have affected the coastline along the Pacific Northwest during historic times. The Fort Point tide gauge in San Francisco recorded approximately 21 tsunamis between 1854 and 1964. The 1964 Alaska earthquake generated a recorded wave height of 7.4 feet and drowned eleven people in Crescent City, California. For the case of a far-field event, the Bay area would have hours of warning; for a near field event, there may be only a few minutes of warning, if any.

A tsunami originating in the Pacific Ocean would lose much of its energy passing through San Francisco Bay. Ritter and Dupre (1972) estimated runup for the 100-year return period tsunami near the Golden Gate to be 10 feet, which may be regarded as a reasonable maximum for future events. The available data indicate a systematic diminishment of the wave height from the Golden Gate to the head of the Carquinez Strait and on into Suisun Bay, diminishing by approximately 50 percent near San Quentin. The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS (codified as the California Code of Regulations (CCR), 2001 Title 24 Part 2, California Building Code, Chapter 31F (Marine Oil Terminals))) section 3103F.5.7 (Table 31F-3-8) provides estimated tsunami run-up for areas of California. The maximum expected increment of wave height near the Long Wharf for the 100-year return period event is estimated to 7.6 feet, and for the 500-year return period event is estimated to be 13.5 feet. These values are to be added to the maximum high tide heights to determine potential damage.

A recent study prepared for the CSLC (Borrero, Dengler, et. al. (in prep)) investigated the effects of a tsunami at marine oil terminals inside of San Francisco Bay. The results indicate that wave heights at the Carquinez Strait are on the order of 25 percent of the values at Richmond, and 10 percent of the values at the Golden Gate of those presented by Ritter and Dupre (1972) and in the MOTEMS. The areas near the terminals in the Carquinez Strait show a much more muted response to the waves entering the Golden Gate. Also, for the outer Richmond area, which is the location of the Long Wharf, attenuation is on the order of 65 percent as compared to the Golden Gate. Based on this new study, a far field event would be attenuated at the Long Wharf to a positive 3.2 foot wave, and a negative 4.6 foot wave. For a near field event, this study predicts a positive/negative wave of less than 1 foot at the Long Wharf. Based on this new analysis, it is anticipated that the 2001 Title 24, Part 2 California Building Code, Chapter 31F, Table 31-3-8 will be modified (personal comm., Eskijian, 2005).

## Structural Condition of the Long Wharf

### *Design*

The Long Wharf has a long and varied construction history. The original Long Wharf facility, a timber wharf built in 1902, was demolished in 1946. Austin Earl, Consulting Engineer, redesigned the Long Wharf in 1946 and reconstruction began in 1947. In 1974, breasting points and loading platforms were incorporated into the existing structure at Berths No. 1, No. 3 and No. 4, and independent breasting and mooring dolphins and catwalks were added to Berths No. 1 through No. 4. The LSFO pipeway was also added at this time. A vapor recovery system was added in 1991, constructed on a separate platform adjacent to the repair wharf (Berths A and B) (Moffatt & Nichol Engineers 1997).

A 4,200-foot-long (.80 miles) causeway connects the Long Wharf – the main wharf and the smaller repair wharf – to the shore. A new steel trestle and the LSFO pipeway run parallel to the causeway (Figure 4.11-1). Several structures, including an office building (control house), machine shop, utility wharf, oil spill response building, and vapor recovery system are also located on the Long Wharf. The Long Wharf has a total dead weight of 30,000 tons. Original design loads for the Long Wharf are not readily available and may not be known due to the age of the structure.

The causeway and pipeways consist of three distinct structures. The former timber, now steel, trestle supports only piping. On the south side of the trestle is the reinforced concrete causeway (main), built in 1947, and on the north side is the concrete pipeway (LSFO), built in 1974.

The main Long Wharf (Berths Nos. 1 - 4), approximately 2,460 feet (.47 miles) long and 110 through 132 feet wide, tees off the causeway extending approximately 670 feet south and 1,790 feet (.34 miles) north from it. Berth No. 1 mooring dolphin is approximately 400 feet long, and Berth No. 4 mooring dolphin is approximately 500 feet long. The main Long Wharf is supported by approximately 2,000 piles, divided into 206 bents, and spaced on 12-foot centers. Approximately 1,600 piles are vertical 18-inch-square pre-cast concrete piles and 400 are battered 22-inch-square concrete jackets over 14-inch diameter timber piles (Moffatt & Nichol Engineers 1994). The pile lengths vary from approximately 90 to 100 feet. The deck on the main Long Wharf is a 4.5-inch thick poured-in-place concrete slab over a series of 5.5-inch thick pre-cast concrete panels spanning the deck girders. Battered piles for the main Long Wharf and other portions of the Long Wharf are sloped at 5:12 (horizontal to vertical). The design capacities of the piles are approximately 25 tons for the vertical piles and 20 tons for the battered piles (Moffatt & Nichol Engineers 1995).

The repair wharf (Berths A and B) is approximately 480 feet long and juts out to the southeast near the wharf end of the causeway. The repair wharf rests on approximately 220 piles, grouped into 41 bents spaced at approximately 12 feet on-centers. The pile lengths vary from 95 to 105 feet.

The office, or control, building slab – 42 feet by 121 feet – is supported on a series of vertical 18-inch piles. There are four 22-inch battered piles at each end along its east/west axis and a row of battered piles along the north side.

*Upgrades*

Several upgrades to the Long Wharf have been made over the years, and in the mid-1990s, major upgrades were undertaken. In 1994, Moffatt & Nichol Engineers inspected and analyzed the Long Wharf structure in detail, and recommended upgrading several sections of the Long Wharf (Moffat & Nichol Engineers 1994). During these inspections, Moffatt & Nichol determined that the wood cores of the pilings were deteriorating. Based on the results and recommendations of this study, a 5-year repair/rehabilitation program and a separate seismic evaluation were initiated.

In 1995 and 1996, when initial repairs to the damaged concrete piles on the main Long Wharf revealed extensive internal deterioration of certain battered piles, work was halted. Subsequent seismic analysis determined that moderate to severe earthquakes on the nearby Hayward Fault could cause moderate to extensive damage to the Long Wharf (Moffatt & Nichol Engineers 1997), and that:

- A relatively moderate earthquake (maximum probable, 72-year event) on the Hayward Fault could cause significant damage and possible collapse to the causeway. The main Long Wharf piles would sustain moderate, but significant, repairable damage. About 25 percent of the piles at the main Long Wharf would need to be repaired; and

- A severe earthquake (maximum credible, 475-year event) on the Hayward Fault could collapse the causeway. The main Long Wharf piles would sustain extensive damage. About 60 percent of the piles would be damaged below the mudline and would probably not be repairable.

The seismic analysis did not examine the timber trestle, as interim repairs and replacement of the timber trestle were already underway. The geriatric timber trestle was considered to be a weak link, and replacement became the preferred option.

In addition to reviewing Long Wharf conditions, Moffatt & Nichol also:

- Evaluated the seismic analyses and weighing available alternatives, established a seismic upgrade plan for the Long Wharf to effectively resist a maximum credible earthquake and result in only relatively minor and repairable damage in the event of a seismic event;

- Summarized the previously proposed rehabilitation plan and work performed to date, re-evaluated, updated, and revised as necessary, previously proposed rehabilitation plan items, to reflect subsequent information and work performed to date;

- Prioritized required seismic strengthening and maintenance repair items; and

- Established an Upgrade Master Plan, combining seismic strengthening and repair objectives, remaining site evaluations and permitting and operational constraints.

In 1995, Dames and Moore prepared a detailed geotechnical study required to complete the structural analysis and design upgrades. Dames and Moore generated site-specific response spectra for the return periods of 72, 475, and 950 years. Two methodologies were used to obtain the site-specific spectra. The first used the computer program SHAKE, and the second one was based on a probabilistic seismic hazard analysis (PSHA). The two approaches showed agreement.

The structural analyses indicated that the Long Wharf could be strengthened to withstand a moderate earthquake (maximum probable, 72-year event) on the Hayward Fault with only minor, repairable damage, and to withstand a severe earthquake (maximum credible, 475-year event) on the Hayward Fault without collapsing, and with all resulting damage repairable. In terms of a performance requirement, no oil would be spilled with these scenarios.

These studies determined that the best way to achieve these performance objectives would be to limit the displacement of the various components of the Long Wharf, so that no plastic hinges in the existing concrete piles would occur. The preferred strengthening configuration was to install a series of large diameter vertical steel piles at selected locations along the east side and the north and south ends of the Long Wharf, and along the north side of the causeway. Based on these conclusions, Moffatt & Nichol Engineers (1997) prioritized seismic strengthening and repairs for the Long Wharf and the facilities, with precedence given to the central section of the Long Wharf (location of the control building) and then the causeway. The second priority was to complete the rehabilitation of the remainder of the main wharf.

Seismic strengthening for the causeway, trestle, and office building included installation of new piles and slab reinforcement. Seismic upgrades for the causeway included installation of 244 new 30-inch-diameter steel-pipe piles and installation of four-pile bents spaced 40 feet on-center along the length of the causeway. The upgrade of the geriatric timber trestle to new steel included the removal of 945 pilings and the replacement with about 120 new steel 18-inch diameter piles, along with the installation of two-pile bents spaced on 20-foot centers. The new piles are 80 feet in length, embedded about 50 feet into the bay mud. The seismic upgrade for the control building included installation of nine 24-inch- to 48-inch-diameter steel-pipe piles, 100 feet long and embedded approximately 70 feet. The existing base concrete slab was connected to the new piles by new reinforcing bars (2-¼ inch diameter) and steel collars. The reinforcing bars were placed beneath the existing slab, encased in a new concrete slab, and secured to the piles with the steel collars. The steel bars were post-tensioned after the new underlying slab had set. A similar configuration, using 24-inch-diameter piles and smaller diameter reinforcement (1-1/8 inch bars) were used to upgrade the machine shop, located in the central portion of the Long Wharf near the control building.

Seismic strengthening of the main Long Wharf was completed in 2000. Upgrades for the main Long Wharf included removal of 22 pilings and installation of 104 new 48-inch-diameter steel piles in the main section of the Long Wharf and 8 new 36-inch steel piles in the central section of the Long Wharf. The piles are 80 feet long and embedded approximately 50 feet into the Bay mud. A total of 26 large 4-pile bents have been installed along the main Long Wharf, and 3 large bents along the repair wharf in addition to 12 new 48-inch diameter piles. Construction of each bent required the cut-out of a 22-foot-square section of the Long Wharf deck. The new isolated bents consist of four 48 inch diameter piles, spaced 12 feet on center, in both directions, embedded in a new 6 foot thick by 22 foot square reinforced concrete pile cap. These new bents are structurally isolated from the existing wharf structure.

Chevron, in cooperation with California's Strong Motion Instrumentation Program (CSMIP) installed accelerometers on the Long Wharf. These accelerometers are mounted at strategic locations and serve the following purposes:

1. Validate the seismic response of the structure, and provide time history acceleration and displacement records to compare with the recent seismic analysis.

2. Provide an acceleration time history and in-structure response spectrum that may be useful in assessing damage to other marine oil terminals in the area. The Long Wharf records may provide an indicator of whether or not other marine oil terminals should remain operational after an earthquake in the Bay area.

3. Assist in the decision to remain operational following an earthquake. If the maximum acceleration or response spectrum appears to be near the design capacity of the structure, a decision to shutdown operations and/or begin a detailed underwater inspection process to assess damage may be required. This information may also provide some indication of potential damage to pipelines or other mechanical systems on the wharf.

The remaining structural upgrade, completed in 2002, was the rehabilitation of damaged piles that had severe spalling. This completed the list of recommended seismic strengthening and repairs from the 1997 study.

Other non-seismic upgrades include a new diesel fire pump located on the Long Wharf along with a new 10-inch fire water line. In addition, in 2004 a complete upgrade of the electrical system of the Long Wharf was completed.

The Long Wharf rehabilitation program has been consistent with the CSLC's Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) which was codified as CCR Title 24, Part 2, Chapter 31F (Marine Oil Terminals) and becomes effective on February 6, 2006. MOTEMS requires:

a. All MOTs must perform an above-the-water engineering audit every 3 years; and

b. For high risk MOTs (as defined in the MOTEMS), such as the Chevron Long Wharf, the operator has 30 months (from 2/6/2006) to perform the first engineering "audit". Thus, this would be in August 2008, but would not include the seismic analysis, mooring analysis, or other assessments that have already been performed. The audit will require an underwater inspection, a thorough above-the-water inspection, and an extensive walk-through, to verify compliance with MOTEMS. In MOTEMS, for concrete structures that are in good condition, an underwater inspection is required every 6 years (maximum allowable between u/w inspections). Pending future changes, such as larger vessels, higher impact velocities or structural degradation, the MOTEMS may require additional structural, mooring, pipeline or other analyses and upgrades, to remain compliant.

However, due to the present upgraded condition of the Long Wharf, additional upgrades or rehabilitation to remain MOTEMS compliant is considered to be minimal.

### 4.11.2 Regulatory Setting

The laws and regulations regarding soils and geologic conditions that would apply to the proposed Project were addressed in Section 4.2, Water Quality, and Section 4.3, Biological Resources. The requirements of the MOTEMS generally represent the best current practice of industry and meet the standards of the "best achievable protection of public health and safety and the environment" prescribed by Section 8755 of the Public Resources Code.

### 4.11.3 Significance Criteria

Earthquakes can cause major damage to marine structures. Damage may be eliminated or minimized if seismic analysis/design has been incorporated into the criteria and structural design. Significant types of seismic damage can include:

- Settlement of the soil beneath the Long Wharf's foundation that could substantially damage structural components of the Long Wharf;

- Ground motion due to a seismic event that could induce liquefaction, settlement, or a tsunami (primarily vessel impact) that could damage structural components of the Long Wharf;

- Deterioration of structural components of the Long Wharf due to corrosion, weathering, fatigue, or erosion that could reduce the structural capacity, which could then fail to meet seismic performance requirements;

- Increase in the structural dead load (affecting the seismic analysis), , vessel size or a change in a mooring configuration (mooring/berthing issues) that might exceed the existing structural capacity of the Long Wharf, and thus reduce the structural integrity; and

- Damage to petroleum pipelines and/or valves along the pipeways from any of the above conditions that could release crude/product into the environment.

## 4.11.4 Impacts Analysis and Mitigation Measures

### 4.11.4.1 Geotechnical Conditions of the Long Wharf

**Impact GEO-1: Ground Rupture and Seismically Induced Landslides**

**The Long Wharf is not located in the Alquist-Priolo earthquake fault zone. Surface rupture from known active faults is not anticipated, and impacts would be less than significant (Class III). Seismically induced landslides are unlikely as the underlying sea bottom is relatively flat (Class III impact).**

Ground rupture is unlikely to occur because known active faults do not underlie the immediate project area. Seismically induced landslides are unlikely because the underlying sea bottom is relatively flat. Therefore, ground rupture, and landslides do not pose significant adverse impacts (Class III) to the Long Wharf.

GEO-1: No mitigation is required.

**Impact GEO-2: Groundshaking**

**Upgrades have been completed at the Long Wharf that conform to CSLC's MOTEMS. Potential impacts from groundshaking are adverse, but less than significant (Class III).**

The Long Wharf is located in the greater San Francisco Bay Area, which is susceptible to the effects of strong ground shaking due to earthquakes. According to the Working Group on California Earthquake Probabilities (WGCEP 1990), there is a 67 percent chance that a magnitude 7.0 or greater earthquake will occur in the greater San Francisco Bay Area by 2020. The WGCEP (1990) also estimates that there is a 28 percent chance that a magnitude 7.0 or greater earthquake will occur on the nearby Hayward Fault by 2020.Based on these studies, it is very likely that the Long Wharf will experience some strong ground shaking over the life of the proposed lease.

Recent upgrades to the Long Wharf have been designed to mitigate the effects of strong ground shaking. These upgrades were designed based on the seismic input criteria developed by Dames & Moore (1995, 1998), and the structural analysis/design rehabilitation by Moffatt & Nichol Engineers (1994, 1995, 1997). The seismic criteria includes both a 72 and 475 year return period earthquake, corresponding to annual probability of exceedance of 50 percent and 10 percent based on a 50 year remaining life of the structure. The performance goals and criteria set by Moffatt & Nichol (1997) require that the structure withstand the 475-year return period earthquake with minor damage that can be easily repaired. No oil should be spilled, and pipelines should remain elastic. These seismic loads and the analysis/design rehabilitation are in conformity with the new CSLC MOTEMS.

For soil-structure interaction, the pile design was based on actual load test data conducted by Dames & Moore (1998). Based on the results of these studies, new piles were designed for the various sections of the Long Wharf, including the causeway and trestle, office building, machine shop, and the main Long Wharf. Some of these upgrades were installed in 1998 and 1999. Remaining retrofit construction was completed in 2000.

The completed seismic upgrades for the causeway and timber trestle included installation of 30-inch- and 18-inch-diameter steel-pipe piles (replacing timber piles) that are 80 feet long and embedded approximately 50 feet into Younger Bay Mud. These piles were installed in 4-pile bents spaced 40 feet on center along the length of the causeway and trestle. Seismic upgrades for the office building include 24-inch- and 48-inch-diameter steel-pipe piles that are 100 feet long and embedded approximately 70 feet into Younger Bay Mud.

Seismic upgrades for the main Long Wharf were completed in 2000 and meet the performance standards prescribed in the MOTEMS. Seismic upgrades for the main Long Wharf included four-pile bents with 48-inch-diameter steel piles that are 80 feet long and embedded approximately 50 feet. A total of 26 large bents have been installed along the main Long Wharf, and 3 large bents along the repair wharf. The bents are made up of 4 steel piles spaced 12 feet on center in both directions that are imbedded in a new 6-foot thick by 22-foot square reinforced concrete pile cap. The bents are not bonded to the existing Long Wharf.

These seismic upgrades should prevent the Long Wharf and causeway from sustaining major damage; however, some limited damage to the structure is likely to occur during a 475-year return period earthquake. This limited damage is considered an adverse, but less than significant (Class III) impact.

In addition to the main structures of the Long Wharf, ancillary equipment, such as pipelines, valves, and support substructures could be affected by strong ground shaking. Pipelines are typically flexible enough to withstand some movement without failure. If a large seismic event were to occur during loading/offloading operations, the pipelines could fail, resulting in the release of petroleum. During their inspection, Moffatt & Nichol Engineers (1997) found that the LSFO pipeway, which was constructed in 1972, was in very good condition. The seismic upgrade program reduced potentially significant, adverse impacts of a pipeline rupture to a less than significant level (Class III) and no further mitigation is required. In addition to the condition of the pipeway, emergency cleanup measures are in place to minimize the adverse impacts that a spill might have on the surrounding environment. Specific discussion of spill measures is presented in Section 4.1, Operational Safety/Risk of Accidents.

<u>GEO-2: No mitigation is required</u>.

**Impact GEO-3: Liquefaction and Seismically Induced Settlement**

**Bay Mud beneath the Long Wharf is considered non-liquefiable; therefore, the impact of liquefaction on the structure would be adverse, but less than significant (Class III). Seismically induced settlement was taken into account for the seismic retrofit design and structural upgrade program. Thus, impacts associated with seismically induced settlement have been addressed and the potential for impact is adverse, but less than significant level (Class III).**

*Liquefaction*

Liquefaction is a phenomenon whereby insufficiently dense saturated granular soil temporarily loses strength and bearing capacity during and immediately following seismic shaking. Sediments underlying the Long Wharf are comprised of cohesive (clayey) soils of Younger Bay Mud, varying in thickness from 50 to 80 feet. Younger Bay Mud beneath the Long Wharf is considered non-liquefiable; therefore, the impact of liquefaction on the structure would be less than significant (Class III).

*Seismically Induced Settlement*

Seismically induced settlement can occur beneath structures that are founded in relatively weak soils such as Bay Mud. The upper portions of the Younger Bay Mud underlying the Long Wharf could settle during an earthquake, which could lead to some damage of the structural components. Damage to the structure could be caused by downdrag of the piles supporting the Long Wharf. The supporting piles develop their load capacity primarily through skin frictional resistance, or interaction with the soil surrounding the length of the pile. Seismically induced settlement was taken into account for the seismic retrofit design prepared by Moffatt & Nichol Engineers (1997) and Dames & Moore (1998). The structural upgrade program reduced any significant, adverse impacts associated with seismically induced settlement to a less than significant level (Class III) and no further mitigation is required.

GEO-3: No mitigation is required.

**Impact GEO-4: Tsunami**

**Long Wharf operators may not have adequate warning time to allow a vessel to depart from the Long Wharf to avoid damage to the vessel and/or the Long Wharf from a tsunami. Impacts are considered significant adverse (Class II) impacts.**

A tsunami originating in the Pacific Ocean would lose much of its energy as it passed through San Francisco Bay. A far field tsunami generated 8.5 foot wave height at the Golden Gate would attenuate to 3.14 feet near the Long Wharf, and a near field tsunami generated 1.96 foot wave height at the Golden Gate, would attenuate to less than one foot near the Long Wharf. According to older design documents (Sverdrup & Parcel and Associates, Inc. 1979), the Long Wharf is designed for maximum wave heights of

5 feet. Still, the effects of a large tsunami wave on the Long Wharf could be significant (Class II). In addition, for near shore events that do not allow time for vessel departure, a moored vessel might damage both the Long Wharf and the vessel itself, and could result in a significant adverse impact (Class II).

A seiche is a standing-wave oscillation of the surface of water in an enclosed basin, such as a bay or lake. A seiche can vary in period and in height from several centimeters to a few meters, and can be initiated by local atmospheric changes aided by winds, tidal currents or an earthquake. At least one seiche occurred in the Bay in 1941, generated by gale force winds. The likelihood of a seiche occurring within the Bay that could exceed the maximum wave height for the Long Wharf is uncertain but unlikely. The impact of a seiche on the Long Wharf is considered adverse but less than significant (Class III).

Mitigation Measures for GEO-4:

**GEO-4.** As soon as possible, after notification of a tsunami, Long Wharf operators shall release the vessel from its mooring and the vessel shall move away from the Long Wharf.

Rationale for Mitigation: Even with structural upgrades, the Long Wharf still has the potential to be damaged if a vessel is moored during a tsunami event. If a vessel does not have time to move to deeper water, a plan must be in place and be implemented, to attempt to protect both the vessel and the Long Wharf, to the greatest extent feasible.

### 4.11.4.2 Structural Conditions of the Long Wharf

**Impact GEO-5: Structural Conditions of the Long Wharf**

**Upgrades to the various components of the Long Wharf have been completed and meet the performance criteria prescribed in the CSLC MOTEMS. As completed, there are no adverse impacts (Class III) associated with the Long Wharf.**

For the Long Wharf to withstand seismic, mooring, berthing and other loads, all structural components must be adequately analyzed and designed. In 1946 and 1947, the original Long Wharf structure was demolished and a new Long Wharf was constructed. About 50 years later, extensive inspections of the Long Wharf's pile foundation by Moffatt & Nichol Engineers (1994) found that many of the timber piles installed in 1947 for the timber trestle had deteriorated to the point that they were no longer load bearing. They found that concrete components from the 1947 construction were in relatively good condition. They also noted that the LSFO pipeway and the external dolphins, which were added in 1972, and the vapor recovery unit support structure added in 1992, were all in very good condition. Moffatt & Nichol recommended replacement of many of the piles along the timber trestle, and performed engineering analysis to determine the capacity of the Long Wharf, under newly developed seismic load criteria. They concluded that the Long Wharf would sustain substantial damage during a 475-year return period seismic event (10 percent probability of exceedance in 50 years).

Subsequent engineering studies by Moffatt & Nichol (1995, 1997) and Dames & Moore (1995, 1998) provided recommendations to rehabilitate the structure to withstand a 475-year return period seismic event with only minor damage that can be easily repaired. Upgrades to the various structures of the Long Wharf have been completed and meet the level prescribed in the CSLC MOTEMS. As completed, there are no adverse impacts (Class III) associated with the Long Wharf. And to be consistent with the MOTEMS, periodic inspections, both above and below the water line will continue for the remaining life of the structures. Additional requirements will be necessary following an incident, such as an earthquake, vessel impact, fire/explosion or other event.

GEO-5: No mitigation is required.

**Impact GEO-6: Future Consideration of Larger Vessels at Berth No. 4**

**A preliminary analysis indicates that the structural capacity of the breasting dolphins and the main Long Wharf would need to be increased, in order to berth/moor larger vessels at Berth No. 4. Significant, adverse impacts (Class II) could occur without proper design and construction of seismic and mooring improvements addressing this potential for larger vessels at Berth No. 4.**

Over the 30-year proposed lease period, larger vessels may possibly be moored at Berth No. 4. Currently, the BCDC allows mooring of vessels with 150,000 tons of cargo at the Long Wharf. Berth No. 4 currently handles the largest ships, including VLCC's up to 272,000 DWT. A preliminary mooring analysis to accommodate double-hull ships up to 292,000 DWT indicates that modifications would be required for the breasting dolphins, the main Long Wharf structure, the loading arms, and also some dredging would have to be done to facilitate a wider vessel. In addition, a seismic reassessment would be required along with these structural modifications. Significant, adverse impacts (Class II) could occur without proper design and construction of these improvements required for the mooring of larger vessels at Berth No. 4.

Mitigation Measures for GEO-6:

**GEO-6.** Additional mooring and structural analyses will be required and results implemented prior to the berthing of larger double-hulled vessels at Berth No. 4.

Rationale for Mitigation: A preliminary mooring analysis indicates that mooring of larger double-hull vessels at Berth No. 4 will require dredging a wider berth, raising the height of the loading arms, and upgrading the breasting dolphins and main Long Wharf. The structural capacity of the breasting dolphins and the main Long Wharf would need to be increased to withstand increased design winds from the south and southwest that would be pushing against the larger vessels. Seismic considerations would also have to be included in final design of any modifications. Alternatively, a reduction in the operating wind-envelope within which these vessels could moor at Berth No. 4 should be considered. Implementation of these modifications would reduce impacts to a less than significant level.

### 4.11.5 Impacts of Alternatives

**Impact GEO-7: No Project Alternative**

**Removal of the Long Wharf would result in no geotechnical impacts and would eliminate long-term potential for structural damage to the facility (Class IV).**

Under the No Project Alternative, Chevron's lease would not be renewed and the existing Long Wharf would be subsequently decommissioned with its components abandoned in place, removed, or a combination thereof. The decommissioning of the Long Wharf would follow an Abandonment and Restoration Plan as described in Section 3.3.1, No Project Alternative.

Under the No Project Alternative, alternative means of crude oil / product transportation would need to be in place prior to decommissioning of the Long Wharf, or the operation of the Chevron Refinery would cease production, at least temporarily. It is more likely, however, that under the No Project Alternative, Chevron would pursue alternative means of traditional crude oil transportation, such as a pipeline transportation, or use of a different marine terminal. Accordingly, this EIR describes and analyzes the potential environmental impacts of these alternatives. For the purposes of this EIR, it has been assumed that the No Project Alternative would result in a decommissioning schedule that would consider implementation of one of the described transportation alternatives. Any future crude oil or product transportation alternative would be the subject of a subsequent application to the CSLC and other agencies having jurisdiction, depending on the proposed alternative.

Decommissioning including removal of piers would be subject to other CEQA review, but could result in a temporary disturbance to sediment as discussed in Section 4.2, Water Quality, but no geotechnical impacts would be expected. Following decommissioning of the Long Wharf, there would be no potential for structural damage that could result in damage to pipelines, and subsequent pipeline spills, as discussed in Section 4.1, Operational Safety/Risk of Accidents and a beneficial impact (Class IV) would result. Impacts would be transferred to other Bay Area marine terminals.

<u>GEO-7: No mitigation is required</u>.

**Impact GEO-8: Full Throughput via Pipeline Alternative**

**New overland pipelines would likely be required to maintain the current levels of production for the type of crude oil processed at the facility. Special design or**

**flexible connections would be required for areas where pipelines cross active faults and at connecting points to valves and storage facilities, reducing potential impacts to less than significant (Class III). Damage to overland pipelines caused by improper engineering design, corrosion, joint failure, and vandalism could result in significant, adverse (Class II) impacts.**

The Refinery currently receives approximately 245,000 bbls of crude oil a day from the Long Wharf and other pipelines. The No Project Alternative would require the same level of operation to occur by transport of crude and product via pipelines. New overland (above-grade or buried) pipelines would most likely be required to maintain the current levels of production for the type of crude oil processed at the facility. Pipelines are typically flexible enough to withstand strong ground shaking without rupture. Special design or flexible connections need to be considered for areas where pipelines cross active faults and at connecting points (hard) to valves and storage facilities. Leaks from pipelines can be caused by seismic displacement, improper engineering design, corrosion, joint failure and vandalism, which have the potential to result in significant, adverse (Class II) impacts. Discussion of the consequences of spills is presented in Section 4.1, Operational Safety/Risk of Accidents.

Mitigation Measures for GEO-8:

**GEO-8.** Damage to pipelines by seismic displacement or other hazards, can be minimized by evaluating proposed routes and providing proper engineering design. Periodic inspection, maintenance, and retrofitting of pipelines shall also be conducted to reduce the possibility of pipeline failure due to corrosion and fatigue.

Rationale for Mitigation: Pipelines are typically flexible enough to withstand strong ground shaking and displacement, without failure. Special design or flexible connections need to be considered for areas where pipelines cross active faults and at connecting points to valves and storage facilities. With proper design for maximum seismic displacement, along with periodic maintenance and inspection, any significant, adverse impacts due to groundshaking would reduce the impact of pipeline rupture. Periodic maintenance and inspection can also reduce the potential for leaks caused by corrosion and joint failure. Discussion of the consequences of spills is presented in Section 4.1, Operational Safety/Risk of Accidents. Implementation of the mitigation measures would reduce impacts to less than significant.

**Impact GEO-9: Conceptual Consolidation Terminal Alternative**

**Geologic and seismic considerations for a new terminal would be addressed as a separate CEQA document. Pipeline connections to the Refinery would have the same consequences as for the Full Throughput via Pipeline Alternative (No Project Alternative), including Class II impacts for pipelines.**

The consolidation facility was assumed to be located on the coast of Contra Costa County north of the Long Wharf. The same geologic and seismic impacts would apply to the consolidation terminal as to the Long Wharf; however, specific impacts would be addressed in a separate CEQA document. Pipeline connections to the consolidation facility would be the same as those discussed for the Full Throughput via Pipeline Alternative.

Mitigation Measures for GEO-9:

**GEO-9.** Implement MM GEO-8.

Rationale for Mitigation: Pipelines are typically flexible enough to withstand strong ground shaking and displacement without rupturing. Special design or flexible connections need to be considered for areas where pipelines cross active faults and at connecting points to valves and storage facilities (hard/rigid connections). With proper seismic design any significant, adverse impacts due to groundshaking would reduce the impact of pipeline rupture. Periodic maintenance and inspection can also reduce the potential for leaks caused by corrosion and joint failure. Discussion of the consequences of spills is presented in Section 4.1, Operational Safety/Risk of Accidents. Implementation of the mitigation measures would reduce impacts to less than significant.

### 4.11.6 Cumulative Projects Impacts Analysis

**Impact CUM-GEO-1: Impacts of Seismic Forces on Cumulative Projects**

**Wharf structures are designed to withstand large lateral forces, thus are not expected to have significant damage from most earthquake events. No adverse cumulative impacts would result (Class III). Cumulatively, if many pipelines were to rupture and leak oil or product significant adverse impacts to the surrounding environment (Class I or II) could occur.**

The shoreline of San Francisco Bay, Carquinez Strait and Suisun Bay is home to many marine and industrial facilities that are susceptible to earthquake-related damage. The 1989 Loma Prieta earthquake caused extensive damage to various structures in the city of Oakland and its port facilities (Benuska 1991; Borchardt 1991). Liquefaction and seismically induced settlement of loose and soft soils caused most of the damage, which included failure of bridge supports and damage to storage tanks. Most wharves, constructed are as highly redundant structures, experienced little or no damage during this earthquake. Wharves are not expected to fail catastrophically during a 475 year return period earthquake, and thus no significant impact is expected (Class III). However, ruptured pipelines and storage tanks could release oil or product that could result in significant adverse impacts to the surrounding environment (Class I or II).

Mitigation Measures for CUM-GEO-1:

**CUM-GEO-1.** Implement proposed Project MM GEO-4 and MM GEO-6.

Rationale for mitigation: Mitigation for the Long Wharf includes adherence to those measures presented in the Geotechnical Issues/Structural Integrity section. Those measures are specific to the Long Wharf and involve determination of any corrections that may be required to ensure structural integrity. In response to accidental conditions, each project in the cumulative baseline would react in a different manner to seismic or structural stresses and require individual mitigation. The Long Wharf would contribute in an incremental manner to cumulative impacts. Because the Long Wharf has completed a major structural upgrade, its contribution to the cumulative environment impacts is considered small.

Table 4.11-2 summarizes Geological/Structural Integrity impacts and mitigation measures.

**Table 4.11-2**
**Summary of Geological/Structural Integrity Impacts**
**And Mitigation Measures**

| Impacts | Mitigation Measures |
|---|---|
| **GEO-1:** Ground Rupture and Seismically Induced Landslides | **GEO-1:** No mitigation required. |
| **GEO-2:** Groundshaking | **GEO-2:** No mitigation required. |
| **GEO-3:** Liquefaction and Seismically Induced Settlement | **GEO-3:** No mitigation required. |
| **GEO-4:** Tsunami | **GEO-4:** Vessels will be released from Long Wharf and move away from the Long Wharf after the notification of a tsunami. |
| **GEO-5:** Structural Conditions of the Shore Long Wharf | **GEO-5:** No mitigation required. |
| **GEO-6:** Future Consideration of Larger Vessels at Berth No. 4 | **GEO-6:** Additional mooring and structural analysis will be required prior to berthing of double-hulled vessels at Berth No. 4. |
| **GEO-7:** No Project Alternative | **GEO-7:** No mitigation required. |
| **GEO-8:** Full Throughput via Pipeline Alternative | **GEO-8:** Preventative measures will be taken to prevent the potential of pipeline rupturing. |
| **GEO-9:** Conceptual Consolidation Terminal Alternative | **GEO-9:** Implement MM GEO-8. |
| **CUM-GEO-1:** Impacts of Seismic Forces on Cumulative Long Wharf Facilities | **CUM-GEO-1:** Implement MM GEO-2 through MM GEO-6. |

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